

Dredging/Dredged Material Management Risk Assessment

PURPOSE: This technical note explains the use of risk assessment to facilitate dredged material management decision-making in navigable waterways by U.S. Army Corps of Engineer (USACE) project managers and field operations personnel. The document does not promote risk assessment as a tool for use in every dredged material management decision. It is likely to be most useful, and most used, in those cases that constitute the exception rather than the rule. The use of risk assessment is intended to supplement the analytical options currently available to dredged material managers by building on the existing technical framework (U.S. Environmental Protection Agency (USEPA)/USACE 1992) and the existing tiered approaches (USEPA/USACE 1991, 1998).

BACKGROUND: Scientific advancements have made possible the collection of large amounts of complex information regarding the environmental aspects of dredging and dredged material disposal. The dredged material manager must often use "best professional judgement" to weigh multiple and sometimes conflicting lines of evidence to reach a decision. Environmental risk assessment provides a stepwise framework for the integration of complex information to yield quantifiable estimates of risk including uncertainty. In addition, risk assessment allows the dredged material manager to make explicit the types of information considered and how a decision is reached regarding the suitability of a dredged material for a particular management option.

INTRODUCTION: This document describes the general components of risk assessment; provides an overview of the risk assessment option as applied to the dredged material management process; and describes various technical documents being prepared or planned to help the USACE field operations staff implement the risk assessment option.

RISK ASSESSMENT: Often, and contrary to a USEPA directive to be transparent, discussion of risk assessment is obscured with technical jargon and "terms of art." This document attempts to provide nontechnical definitions for such terms and emphasizes the initial use of the term in bold italics.

What is a risk assessment? *Risk assessment* is the process of evaluating the impact of a *stressor* (e.g., a chemical or physical condition) upon the health of individual humans or the environmental well being of a population or community of animals and plants. The former is called *human health risk assessment*, and the latter *ecological risk assessment*. Subsequent sections describe how these two categories of risk assessment differ.

Risk assessment in its more common manifestations is an often used, although not necessarily formally recognized, component of the dredged material management decision-making process. For example, Peddicord et al. (1997) note that the present procedure for evaluating water column impacts in dredged material evaluations (USEPA/USACE 1991, 1998) is an application of ecological risk assessment.

In its most basic form, risk assessment means answering several simple questions that usually underlie dredged material management decisions:

- Are humans, organisms, or habitats (all called *receptors*) near the proposed dredged material management activities?
- Are chemicals or physical hazards that may affect the survival or reproduction of these receptors associated with the proposed dredged material? The answer to this question is called a *Hazard Identification*.
- Is there a known quantity of the chemical or physical hazard that results in an adverse effect to the likely receptors? This is called *Toxicity Assessment* or *Effects Assessment*.
- Are there any conservative but realistic activities or physical and biological pathways by which the receptors may encounter the chemical or physical hazards associated with a particular proposed dredged material activity? This is termed *Exposure Assessment*.
- Finally, under a specified set of conditions, will this encounter result in an exposure to the chemical or physical hazard at a level known to cause an adverse effect (*Risk Characterization*)?

Generally, if the answer to this last question is no, then the risk associated with the dredged material management decision is assumed to be acceptable. If it is yes, then there is some potential unacceptable risk, and we begin to search for ways to modify management activities or receptor activities to lower the exposure and hence risk. The decision maker asks one additional question:

- How confident are we in our answer (*Uncertainty Analysis*)?

Viewed as a formal approach to answering these simple, commonly posed questions, risk assessment appears as a familiar thought process. Also, dredged material managers and USACE field operations personnel will recognize that the information necessary to answer these questions is nearly always available from data developed as part of the site selection process and tiered evaluation process described in the Dredged Material Testing Manuals (USEPA/USACE 1991, 1998).

A risk assessment is essentially complete when it provides defensible answers to these questions. Current Federal, state, and industry guidance recognizes that risk assessment can be a fairly simple set of answers to these questions. The level of effort needed ranges from a simple "back of the envelope" calculation to something as sophisticated as integrating the various fate and transport models available from USACE (e.g., ADDAMS) with one of several biological food chain models available in the scientific literature. USACE is preparing a series of technical documents that will guide managers and operations personnel in the appropriate application of these models. USACE is also developing a series of technical guidance and support documents and on-line databases to support field operations personnel in conducting risk assessment.

Is risk assessment a proved approach to aid decision-making? The USACE personnel who may use the risk assessment option should recognize that risk assessment is not new or unplowed ground. A prior USACE publication (USACE 1995) noted that risk assessment has a long history in business (e.g., financial risk, insurance industry, cost/benefit analyses), health care (evaluation of drug efficiency versus side effects, efficacy of treatment), and government.

A number of Federal environmental regulatory programs use some form of risk assessment in their decision-making process. Regulatory agencies used the risk assessment approach to develop Federal drinking water standards and ambient water quality criteria, to make decisions regarding environmentally protective concentrations of contaminants under Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) programs, and to develop discharge limits under Clean Water Act provisions.

The United States Congress has renewed its commitment to integrate risk assessment into the regulatory process. The Commission on Risk Assessment and Risk Management published its report on risk assessment in regulatory decision making (Omenn et al. 1997). That the United States Congress mandated this commission to "make a full investigation of the policy implications and appropriate uses of risk assessment and risk management in regulatory programs under various federal laws" reflects governmental concern regarding risk assessment in regulation. The commission report made recommendations for risk-based approaches to nearly all Federal agencies including the Department of Defense, USEPA Office of Water, Occupational Safety and Health Administration, Food and Drug Administration, Department of Agriculture, and Department of Energy. These recommendations indicate that the engineering and water pollution control community will depend even more heavily upon an understanding of risk assessment in the future.

What are the advantages of a risk-based approach for dredged material management? The major advantage of a risk-based approach for dredged material management decision making is that it provides a consistent framework that integrates a wide variety of data and information.

The dredged material manager works within a decision-making system framed by regulation and technical approaches. In their concise review of this framework, Peddicord et al. (1997) note that there are three principal components of dredged material management: (1) site selection; (2) dredged material evaluation (permitting); and (3) site monitoring. The intent of these components is to assure that dredged material management decisions meet the statutory requirement that there be "no unacceptable or undesirable adverse effects."

Currently, these three components form the basis for data collection and environmental analysis of potential impacts associated with dredged material management. The site selection process provides baseline environmental studies of a proposed site. The dredged material evaluation is a four-tiered process as described in the Dredged Material Testing Manuals. An increasing level of information is developed in successive tiers until sufficient data are available to reach a determination regarding the acceptability of the material. Monitoring is a post-site selection and post-dredged material disposal activity to confirm or validate the decision-making process.

It is fair for the dredged material manager or field operations personnel to ask, "If we are essentially collecting all the data and going through the general thought processes for risk assessment anyway, why conduct a formal risk assessment?" The answer is that risk assessment imposes a structure on the data analysis that integrates the information obtained in the site selection process with the data collected and/or generated in Tiers I to IV on the properties of the sediments. A risk assessment further integrates these data with the operational and physical characteristics of the management

technology under consideration. The first step in making this integration is the development of a *site conceptual model* (Figure 1).

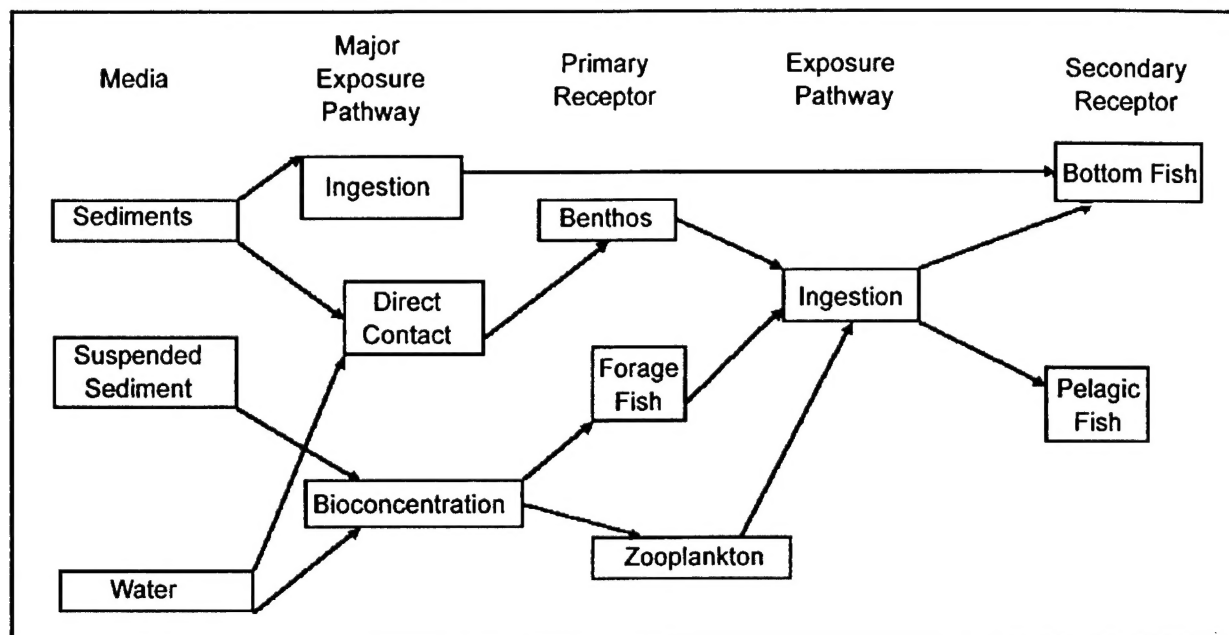


Figure 1. Example of a conceptual model for ecological exposure pathways in an aquatic environment.

Integrating these four data sources lends risk assessment its unique analytical advantages (Table 1): it is site and technology specific; flexible; iterative; inclusive; objective; able to avoid the false positives associated with simple statistical comparisons between the reference and test sediments (i.e., the assumption of risk simply because bioaccumulation is statistically higher when compared to reference); and transparent; and it provides a value added at sites accommodating multiple projects.

Risk assessment also has limitations. In particular, risk assessment results are not transferable from site to site; risk assessments depend on various extrapolations; risk assessment requires careful and complete communication of uncertainties.

Any particular risk assessment conducted at a dredged material site is specific for that site and the proposed dredged material management option. This means that risk assessment results from one site or technology are not directly transferable to another site or another technology. Upon initial examination, this may seem disadvantageous. The manager may ask "Why not do one risk assessment which provides a 'safe' value for use at all sites?" Such an approach would have to be very conservative to cover unanticipated contingencies and variations that will arise among sites and technologies. Such conservatism would be constraining for most sites.

The informed application of risk assessment avoids such constraints by considering site-specific information. In particular, although risk assessors cannot change the toxicity of a specific chemical to a particular organism, they can design alternatives to modify the estimated exposure of the organisms to the chemical based on more accurate site-specific information.

Table 1
Advantages and Limitations of Risk Assessment

Advantages

- **Site and Technology Specific**
Can address site- and technology-specific contingencies and variations without being overly conservative (avoids the pitfalls of numerical standards)
- **Flexible**
Can modify the organism's estimated exposure based on site-specific information
- **Iterative**
Can apply "what if?" scenarios to evaluate the effects of various assumptions or changes in design for a given disposal alternative
- **Inclusive**
Accommodates the input of various interested parties, often referred to as stakeholders
- **Objective**
Focuses upon several endpoints and presents an estimate of risk with reference to these endpoints
- **Avoids false positives**
Avoids false positives associated with simple statistical comparisons between reference and test sediments
- **Transparent**
Makes the decision-making process more explicit
- **Value Added**
Use the same risk assessment at a site with multiple projects over several years

Limitations

- **Results are site specific**
Risk assessment results cannot be universally applied in the same manner as a criterion or advisory level
- **Dependent on extrapolations**
Fate and transport models, toxicity estimates, and exposure estimates will use extrapolations from various data sets with varying degrees of uncertainty
- **Requires careful and complete communication of uncertainties**
The uncertainty in a risk estimate must be explicitly described for each extrapolation or risk estimate

Even relatively complex risk assessments are easily iterated because the calculations of exposure and risk are easily automated on computer spreadsheets. This allows the dredged material manager to apply what-if scenarios to evaluate the effects of various assumptions or changes in a given disposal alternative. This can be a significant advantage in choosing among alternative management options or selecting sites. This property of risk assessment is also useful in attempting to decide how the timing of disposal may affect an outcome by making different assumptions regarding various seasons (i.e., helping to decide upon appropriate "environmental windows").

Risk assessment is inclusive because it can accommodate the input of various interested parties, often referred to as *stakeholders*, in the risk management process. These stakeholders may be regulators, state agencies, commercial interests, or environmental groups. Where appropriate or necessary, the risk assessment considers their input in the development of *exposure scenarios*. The exposure scenarios are the particular, site-specific, and detailed descriptions of how a human or an

ecological receptor may encounter contaminants or a physical disturbance associated with the dredged material option. For example, a state agency may express a specific concern regarding how a management alternative may affect people who fish near the dredged material management site. The risk assessment can then address this concern by developing an exposure scenario with a recreational fisherman using the nearby waters and catching and eating fish with a specific frequency.

Risk assessment is distinct from *risk management*. The National Academy of Sciences (National Research Council 1983) defines risk management as "the process of weighing policy alternatives and selecting the most appropriate regulatory action, integrating the results of risk assessment with engineering data and with social, economic, and political concerns to reach a decision." Under this definition, risk management should reflect local and contemporary concerns and value judgements. However, risk assessment is more objective, focusing upon several *end points* (measurable characteristics of an ecological or human receptor that may be affected by exposure to a physical stress or contaminant) and estimating risk in reference to these. Once the end points are established, the risk assessment proceeds without modification to them. One can change the assumptions of risk assessment regarding technology, exposure scenarios, or site characteristics, but the risk estimate is always the result of comparing exposure to receptors with these fixed, previously established end points.

The risk assessment avoids problems associated with simple statistical comparison to a reference sediment. For example, a dredged material evaluation may indicate that the proposed dredged material has statistically higher bioaccumulation than a reference sediment. However, this does not necessarily mean that the test sediment has a significantly higher toxicological effect. The risk assessment puts the estimate of risk into a broader context that considers the potential for effect in light of a measured toxicological response for a specific chemical under a set of site-specific conditions.

The assumptions of any risk assessment should be clearly stated (USEPA 1992). Statements regarding uncertainty associated with the assumptions should be included, and if possible, the effect of changing the assumptions over some reasonable range should be demonstrated.

A risk assessment for a specific site and project provides "value added" because it is, with modification, easily applicable to other projects at the same site. From project to project the dredged material evaluation may change, but the data from the site selection report remain constant. Therefore, the risk manager, by substituting the project-specific dredged material evaluation data, can use the same risk assessment scenarios at a site with multiple projects over several years. The entire assessment does not have to be reengineered with each new project. However, the assessment will require additional field data to account for accumulative effects associated with multiple projects.

When should the project manager consider applying risk assessment? The project manager should decide to apply a risk assessment within the context of the site selection process and/or the tiered evaluation of dredged material, or when there are unresolved issues with regard to potential human or ecological exposures. Risk assessment is not separate from the current methods

of decision making. It merely enhances them. In the decision-making process, risk assessment applies best in cases where

- Site selection or dredged material evaluation has indicated potential environmental effects.
- It appears that the integration of site selection data and dredged material characterization around site-specific assumptions may improve the decision maker's understanding of the potential for effects.

A formal assessment is not something to be applied to every project. It is most applicable to projects that have

- Reached Tier IV and concern about specific bioaccumulative compounds or toxic compounds remains.
- Potential to affect a local sensitive habitat or species.
- Outstanding exposure issues where a risk assessment will allow realistic use of information about the natural history of a species such as foraging areas, breeding times, and migration patterns.
- Potential human health exposure either directly to sediments or through the food chain.
- Issues associated with environmental windows.

Risk assessment is not applied to the typical dredged material site or project that is easily handled through the existing technical framework. Rather it applies in those cases where an extended analysis allows the dredged material manager to address such real-world conditions as sediment matrix effects, bioavailability, intermittent use of the site by a species of concern, the mitigating effects of a specific management technology, the likely exposure to people fishing recreationally, etc.

Will the use of risk assessment require an expensive or time-consuming data collection program? The site selection process and the dredged material evaluation tiered approach will satisfy most risk assessment data needs (Table 2). These data may have to be reformulated to provide direct answers to the six questions posed earlier. Note that, as shown in Table 2, the current tiered approaches do not explicitly address uncertainty.

The initial question, "Are humans, organisms, or habitats near the proposed dredged material management activities?", is usually directly answered in the baseline studies of the site selection process. These studies generally define and describe sensitive habitats or species, commercially important species using the site, recreational or commercial uses of the site, and the types of biological communities nearby. Risk assessment may require some reformulation or expansion of this information if an analysis of potential exposure pathways reveals data gaps. For example, a risk assessment may require a more detailed description of human use of the site or an expansion of species descriptions to include information on life history. Usually such can be satisfied by an expanded literature review.

The dredged material evaluation will provide the necessary data to address the question of Hazard Identification, "Are stressors associated with a proposed management action that may affect the

Table 2 Information Sources for Risk Assessment Within the Dredged Material Management Program					
Risk Assessment Component	Site Selection Report and Associated Environmental Reports	Tier I	Tier II	Tier III	Tier IV
	Type of Information Available				
	Sensitive Habitats or Species, Commercially Important Species Using the Site, Recreational or Commercial Uses of the Site, Types of Biological Communities Nearby, Describing Technology	Characterize Sediment; Selection of COCs	Predictive Models to Assess Physical Transport and Water Quality Impacts; Theoretical Bioaccumulation Model	Water Column Toxicity; Sediment Toxicity; Bioaccumulation Testing	Chronic Sublethal Sediment Toxicity; Steady-State Bioaccumulation
Identify receptors	✓				
Hazard identification		✓			
Identify COCs		✓			
Toxicity assessment		✓	✓	✓	✓
Exposure assessment	✓	✓	✓	✓	✓
Risk characterization		✓		✓	
Uncertainty					
✓ = information is available for use in a particular section of risk assessment.					

survival or reproduction of these receptors?" The Tier I characterization of the sediments relies on available results of prior chemical testing, measurements of physical characteristics, organic carbon content, grain size, and review of regulatory records and published literature regarding the material to be dredged (published studies, permit reviews, Federal databases, etc.). This information is generally sufficient for a risk assessor to develop the Hazard Identification and a list of **contaminants of concern** (COCs). Note that specifying COCs is an integral part of risk assessment that will have already been accomplished as a Tier I activity based on explicit criteria in the Dredged Material Testing Manuals.

The identification of COCs during Tier I depends in part on the toxicological importance of each contaminant. This Tier I task therefore provides a start on the risk assessment's Toxicity or Effects Assessment, which answers the question, "Is there a known quantity of the chemical or physical hazard that results in an adverse effect to the likely receptors?" The risk assessment may require that this information be reformulated to conform to the parameters used in human health or ecological exposure models. This is generally accomplished by reference to on-line USEPA and USACE databases or an expanded literature review.

The exposure assessment addresses the question, "Are there any conservative but realistic activities or physical and biological pathways by which the receptors may encounter the chemical or physical hazards?" This is a considerable expansion of Tier I sediment characterizations or Tier II modeling activities and also incorporates the bioaccumulation testing conducted in Tier III. This is the risk assessment component that will require the most expansion upon prior data gathering activities because this is the point that integrates the site selection information with the dredged material evaluation. Although it generally will not require new data collection, it will require a reformulation of the information into a site-specific conceptual model. The conceptual model attempts to link management technology, site characteristics, and dredged material evaluations (Figure 1).

In summary, the activities of site selection and dredged material evaluation provide most of the information needed to conduct a risk assessment. There will be some necessary renewed literature reviews and a reformulation of the data, but expensive, time-consuming field data collections are unlikely.

What is the role of risk assessment in the dredged material risk management process? Risk assessment alone cannot compel a decision at a dredged material management site. In those cases where the dredged material manager chooses to apply risk assessment, he or she should consider it as part of a larger risk analysis process that includes risk management. In prior considerations of risk management, USACE (1995) views this process as a function of several factors: risk and uncertainty, cost, schedule, value of resources protected, regulatory requirements, political factors, economic factors, technical feasibility, environmental justice/equity. The role of the risk assessment in this general process is to provide realistic assessments, not hypothetical or highly conservative assessments that do not provide meaningful risk information to decision makers. Within the risk management process, the risk assessment contributes most readily to the evaluation of alternatives.

The Framework Document (USEPA/USACE 1992) provides comprehensive guidance on identifying, screening, and selecting "reasonable" dredged material disposal alternatives. The

primary, although not exclusive, considerations when evaluating disposal alternatives are effectiveness, implementability, and cost. The dredged material manager should ask the following risk-based questions (USEPA 1991) in evaluating disposal alternatives:

- Which alternatives can readily achieve acceptable risk levels in sediment and biota? What uncertainties are involved in this determination?
- Which alternatives will clearly not address the primary exposure pathways identified in the risk assessment?
- Are the expected residual risks or short-term risks from one alternative significantly different from another?
- What other risk-based benefits (e.g., shorter time to achieving goals) are realized by selecting one alternative over another?
- Will implementation of specific alternatives create new, significant exposures or risks to human or ecological populations?
- Is there a need for engineering controls or other measures to mitigate risks during implementation, and are these controls available and reliable?
- Will any of the alternatives present additional risks to threatened populations or communities [minority communities (Executive Order 12898, February 11, 1994, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations"), Native American subsistence fishermen, living resources, endangered species]?

There are four general categories of alternatives:

- *No-Action and Port Operation Alternatives.* In its most elemental sense, the no-action alternative means that the proposed dredging project is rejected, and the contaminated sediments remain in place. This usually leads to one or more "port operation alternatives" such as channel rerouting and lightering.
- *Engineering Alternatives: Dredging.* Dredging and the discharge of sediments at a disposal site are the predominant methods for constructing and maintaining ports, channels, and berthing areas. The dredged material manager should clearly describe his/her selected alternative, including the performance and limitations of the equipment.
- *Engineering Alternatives: Confined Disposal.* Confined disposal can apply at upland or aquatic sites. The Framework Document includes a detailed review of confined disposal alternatives used in the United States, and provides references of more detailed information sources on the subject.
- *Other Engineering Alternatives.* Other engineering alternatives include upland disposal, incineration, separation technologies, and other treatments. Cullinane et al. (1986) and USEPA (1993) provide detailed descriptions of such alternatives, and possibilities for their future applications.

What is the format of a risk assessment? There are numerous program-specific documents that describe the formal components of a risk assessment and detail how to conduct one within the constraints of the program. USACE is preparing a detailed technical guidance document for operations personnel. The dredged material manager should recognize that risk assessments include

several general components based on a USEPA framework (USEPA 1992) and recently published USEPA guidelines (USEPA 1998). These components address the initial questions indicated earlier. The risk assessment process has four general components:

- *Hazard Identification/Problem Formulation.* Hazard Identification is the process of determining whether exposure to a contaminant can cause an increase in the incidence of a particular human health (e.g., cancer, birth defect, etc.) or ecological (e.g., reproductive, lethal, etc.) effect. In ecological risk assessment, the selection of receptors begins in this section, but will continue into the Exposure Assessment.
- *Exposure Assessment.* An Exposure Assessment estimates the magnitude of actual and/or potential human or ecological exposure to a contaminant of concern, the frequency and duration of exposure, and the pathways of exposure for human and ecological receptors. This is the major step in the development of scenarios, and the decisions made during the Exposure Assessment will be critical to the ultimate estimate of risk. To address concerns of stakeholders it is important that this aspect of scenario development be a cooperative effort early in the risk assessment process. An important component of Exposure Assessment is the selection of human and ecological receptors. To a large extent, these will drive the development of exposure pathways.
- *Toxicity Assessment/Effects Assessment.* The Toxicity Assessment summarizes and weighs available evidence regarding the potential for contaminants to cause adverse effects in exposed individuals and provides, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. Current guidance for Ecological Risk Assessment often refers to "Toxicity Assessment" as an "Effects Assessment."
- *Risk Characterization.* The Risk Characterization summarizes and integrates the Exposure Assessment and Toxicity Assessment into a quantitative and qualitative expression of risk. In a human health risk assessment, the Risk Characterization
 - Characterizes carcinogenic effects by estimating probabilities that an individual will develop cancer over a lifetime of exposure based on projected intakes from a given scenario and the information summarized in the Toxicity Assessment.
 - Characterizes noncarcinogenic effects by comparing calculated intakes of substances, based on specific exposure scenarios, to acceptable doses.

Generally in an Ecological Risk Assessment, Risk Characterization evaluates risk by comparing a concentration, dose, or body burden known to produce an effect, with a corresponding measurement or projection of exposure made in the Exposure Assessment (*toxicity quotient method*). The risk assessor may consider the toxicity quotient with other sources of information (biological conditions at the site, information from reference areas) to form a professional opinion regarding potential risk in a *weight of evidence approach*.

The Risk Characterization should also address uncertainty in the analysis of human health and ecological risk. Risk assessments do not generally provide fully probabilistic estimations of risk. Therefore, highly quantitative statistical uncertainty analyses are not common. The Office of Emergency and Remedial Response (USEPA 1989) emphasizes the importance of identifying the key site-related variables and assumptions that contribute most to the uncertainty.

What is the relationship between ecological and human health risk assessment? At most sites, risk assessment will address two general types of risk, ecological risk and human health risk. Ecological risk assessment focuses on potential risk to nonhuman biota likely to occur at a disposal site. Human health risk assessment focuses on carcinogenic and noncarcinogenic risk to humans from potential exposure. A major difference between the two is that a human health risk assessment addresses potential effects to one type of receptor, human beings, while ecological risk assessment can address risk to several receptors, chosen to represent the ecosystem associated with the dredged material disposal site.

These two types of risk assessment address the fate and transport of contaminants in similar if not identical manners. Those physical and chemical processes driving the distribution of contaminants are the same for the two types of risk assessment. The two are linked in that the estimates of contaminant uptake by biota (evaluated in the ecological risk assessment) may result in exposure to humans if people eat that organism. Clearly, the feeding habits of a commercial species, an ecological characteristic, will to a large extent determine whether that species can pass a contaminant on to a human. This is the point where ecological risk and human health risk are most closely linked. They diverge in the discussion of toxicological processes and how these processes relate to potential effects.

Who can conduct a risk assessment? The selection of personnel to conduct a risk assessment depends on the level of complexity addressed in the risk assessment. For example, a rough estimate of exposure based on a simple sediment-water partitioning equation may be sufficient to demonstrate little probability of bioavailability of a chemical, and hence risk. In such a case, operations personnel with expertise in engineering, chemistry, or marine geology may be the only necessary personnel. In the most complex assessments (and these are likely to be the least frequently encountered), an interdisciplinary team of engineers, biologists, chemists, and physical scientists may be necessary.

What new tools are available or under development by USACE to conduct a risk assessment for a dredged material management project? As indicated earlier, risk assessment is well integrated into various state and Federal regulatory programs. With this integration, these programs have developed various risk assessment frameworks, guidance documents, on-line databases, case studies, and program experts available for consultation. USACE is developing or has planned numerous resources for dredged material managers and operations personnel and will publish these sequentially. They include several documents and databases.

- *Ecological and Human Health Risk Assessment Guidance for Aquatic Sites.* This detailed technical document (currently in draft form) includes specific guidance for developing site-specific risk assessments for dredged material management sites in aquatic environments (anticipated publication in winter 1999). It demonstrates the development of conceptual models that show the likely sources of risk, transport pathways, types of receptors, assessment end points, and physical or chemical relationships among them for ecological and human health exposures. This document illustrates the use of risk assessment with a continuous case study and reviews available Federal, regional, and state guidance and methods used by human health and ecological risk assessors. The appendices include a review of the content and availability of various text and on-line information important in conducting

risk assessments; a description of food chain models useful in risk assessment; summaries of the toxicology of likely contaminants of concern at dredged material management sites; and an approach to weight of evidence.

- *The USACE ERED database.* USACE has an on-line Environmental Residue-Effects Database (ERED), which summarizes by organism and chemical some toxicological effects associated with specific levels of contaminants in tissue. This database is operating and accessible on-line through the U.S. Army Engineer Waterways Experiment Station, Dredging Operations Technical Support (DOTS) home page (<http://www.wes.army.mil/el/dots>).
- *Ecological and Human Health Risk Assessment Guidance for Upland Sites.* This document will be similar to the guidance for aquatic sites, but will address risk assessment at upland management sites.
- *Guidance for Assessing "Non-Contaminant" Impacts at Dredged Material Management Sites.* This document will provide guidance for applying risk assessment methods at sites where the sources of impact are physical disturbances. These may include suspended sediments, habitat alteration, or operational interference with critical life stages or functions requiring the development of "environmental windows" into the operational schedule.
- *Guidance for Incorporating Quantitative Uncertainty and Probabilistic Analyses into Risk Assessment at Dredged Material Management Sites.* This document will provide guidance for incorporating probabilistic assessment into the estimates of risk characterization.
- *Guidance for Comparative Risk Assessment.* Comparative risk assessment is of particular importance to risk management when attempting to distinguish among several sites or several management technologies at a site. This document will describe methods for comparing ecological and human health risks among management alternatives.

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U.S. Army Engineer Waterways Experiment Station. (1998). "Use of risk assessment in dredging and dredged material management," Technical Note DOER-R1, Vicksburg, MS.

REFERENCES

- Cullinane, M. J., Averett, D. E., Shafer, R. A., Male, J. W., Truitt, C. L., and Bradbury, M. R. (1986). Guidelines for selecting control and treatment options for contaminated dredged material requiring restrictions," prepared for the Puget Sound Dredged Material Disposal Analysis by U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- National Research Council. (1983). *Risk assessment in the Federal Government: Managing the process*. National Academy Press, Washington, DC.

- Omenn, G. S., Kessler, A. C., Anderson, N. T., Chiu, P. Y., Doull, J., Goldstein, B., Lederberg, J., McGuire, S., Rall, D., and Weldon, V. V. (1997). *Risk assessment and risk management in regulatory decision-making*. Presidential/Congressional Commission on Risk Assessment and Risk Management, Washington, DC, Vol 2.
- Peddicord, R. K., Chase, T., Dillon, T., McGrath, J., Munns, W. R., van de Guchte, K., van der Schalie, W. (1997). "Workgroup Summary Report on Navigational Dredging." *Ecological risk assessment of contaminated sediments*. C. G. Ingersoll, T. Dillon, and G. R. Biddinger, ed. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL.
- U.S. Army Corps of Engineers. (1995). "Hazardous, toxic, and radioactive waste risk assessment," Proponent Sponsored Engineer Corps Training, Training Management Directorate, Huntsville, AL.
- U.S. Environmental Protection Agency. (1989). "Risk assessment guidance for Superfund: Volume I - Human health evaluation manual (Part A)," EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, DC.
- U.S. Environmental Protection Agency. (1991). "Risk assessment guidance for Superfund: Volume I - Human health evaluation manual (Part C, Risk evaluation of remedial alternatives)," Publication No. 9285.7-01, Washington, DC.
- U.S. Environmental Protection Agency. (1992). "Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memo from F. Henry Habicht to Assistant and Regional Administrators, February 28, 1992.
- U.S. Environmental Protection Agency. (1993). "Selecting remediation techniques for contaminated sediment," EPA-823-B93-001, Office of Water, Washington, DC.
- U.S. Environmental Protection Agency. (1998 (14 May)). "Guidelines for ecological risk assessment," *Federal Register* Vol 63(93), 26845-26924.
- U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. (1991). "Evaluation of dredged material proposed for ocean disposal: Testing manual," EPA-503/8-91/001, Washington, DC.
- U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. (1992). "Evaluating environmental effects of dredged material management alternatives - A technical framework," EPA-842-B-92-008, Washington, DC.
- U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. (1998). "Evaluation of dredged material proposed for discharge in waters of the U.S. - Testing manual," EPA-823-B-98-004, Washington, DC.